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(71)Applicant : NIPPON TELEGR & TELEPH CORP <NTT>

(72)Inventor :
KIYOKU KATSUAKI
KASATANI KAZUO
YUDA MASAHIRO
SUZUKI YASUHIRO
MITOMI OSAMU
NAGANUMA MITSURU

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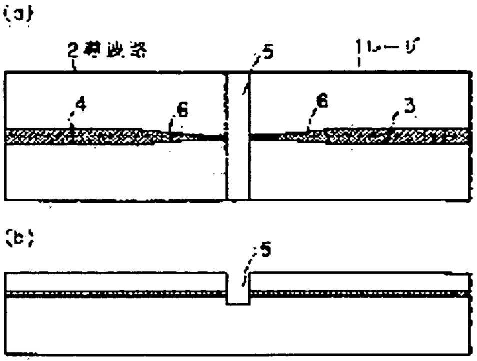
(54) OPTICAL DEVICE

(57)Abstract:

PURPOSE: To improve the coupling efficiency between a semiconductor laser and optical waveguide by forming the core sections of the laser and waveguide in tapered states having narrow core widths near a groove.

CONSTITUTION: The cores 3 and 4 of a semiconductor laser 1 and wavequide section 2 are narrowed (tapered cores 6) in core width toward a groove 5 when they are viewed from the top so that their core widths can become about 1/5 of their proper core widths near the groove 5. Therefore, the mode field diameter of the light guided from the laser 1 is enlarged on the end face of the core of the laser 1 on the side wall of the groove 5 without causing any propagation loss owing to the tapered core 6 and the diffracting effect is reduced. On the other hand, since the core width on the waveguide 2 side also gradually increases as going farther from the groove 5, the mode field diameter enlarged on the side face of the groove 5 again returns to the size decided by the size of the waveguide core 4. Therefore, the coupling efficiency between the laser 1 and waveguide section 2 can be improved, because the enlarged beams are coupled to each other near the groove 5.



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(71)出願人　000004226
日本電信電話株式会社
東京都千代田区内幸町一丁目１番６号

(72)発明者　曲　克明
東京都千代田区内幸町一丁目１番６号　日本電信電話株式会社内

(72)発明者　笠谷　和生
東京都千代田区内幸町一丁目１番６号　日本電信電話株式会社内

(72)発明者　湯田　正宏
東京都千代田区内幸町一丁目１番６号　日本電信電話株式会社内

(74)代理人　弁理士　光石　俊郎　（外１名）

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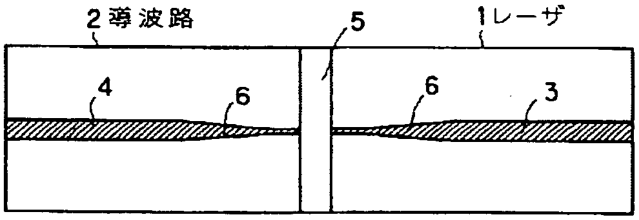
(54)【発明の名称】　光デバイス

(57)【要約】

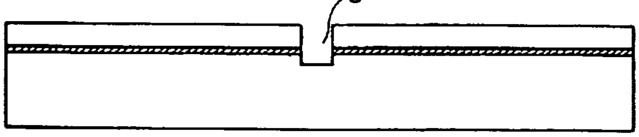
【目的】　半導体基板上に集積化した半導体レーザと導波路とを高結合効率にて形成したものである。

【構成】　半導体レーザ１と導波路２とのそれぞれのコア３，４をその端面側にてテーパ状に形成して、モードフィールド径を拡大するようにしたものである。

(a) 平面図



(b) 断面図



【特許請求の範囲】

【請求項１】　半導体基板上に共振器端面の一端を構成する溝を有する半導体レーザと、前記の溝を介して前記半導体レーザと結合された導波路とを有する光デバイスにおいて、前記半導体レーザと導波路とのそれぞれのコア幅が前記溝近傍においてテーパ状に縮小した構造を有することを特徴とする光デバイス。

【請求項２】　半導体基板上に共振器端面の一端を構成する溝を有する半導体レーザと、前記の溝を介して前記半導体レーザと結合された導波路とを有する光デバイスにおいて、前記半導体レーザおよび導波路とのそれぞれのコアが第一の内部のコアとこの内部のコアを囲む第二の外部のコアからなる二重コア構造を有し、該第一のコア幅が溝近傍でテーパ状に縮小していることを特徴とする光デバイス。

【請求項３】　半導体基板上に共振器端面の一端を構成する溝を有する半導体レーザと、前記の溝を介して前記半導体レーザと結合された導波路とを有する光デバイスにおいて、前記半導体レーザおよび導波路の各コア幅が前記溝近傍でテーパ状に縮小するとともに、該溝の半導体レーザ側端面が光軸に対して垂直をなし、かつ該溝の導波路側端面が光軸に対して傾斜させた構造を有することを特徴とする光デバイス。

【請求項４】　半導体基板上に半導体レーザと、前記半導体レーザと結合された導波路からなる光デバイスにおいて、前記半導体レーザと導波路とのそれぞれのコア幅が結合部でテーパ状に縮小しつつ接続され、該結合部において該半導体レーザ側で光軸に対して垂直な端面をなし、かつ該導波路側で該結合部に近づくに従いテーパ状のコアに近接するような溝を有することを特徴とする光デバイス。

【請求項５】　半導体基板上に半導体レーザと、前記半導体レーザと結合された導波路からなる光デバイスにおいて、前記半導体レーザと導波路とのそれぞれのコア幅が結合部でテーパ状に縮小しつつ接続され、該結合部において該半導体レーザ側で光軸に対して垂直な端面をなし、かつ該導波路側で半導体基板の厚さ方向にＶ字形状となる溝を有することを特徴とする光デバイス。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、光通信または光計測・光交換等に用いられる半導体集積化光源に関するものである。

【０００２】

【従来の技術】光通信、光計測分野の光源としては半導体レーザが利用されているが、機能の向上をはかるためには光源、導波路、受光器の集積化が要求される。従来の集積化モジュールとしては、例えば、石英系導波路で構成されたＰＬＣ回路と半導体発光素子と半導体受光素子をハイブリッドに集積し、光ファイバを結合したピッグテール型部品がある。しかしながら、この半導体発光素子と受光素子のモジュール化技術は、ミクロンオーダーの位置合わせが必要なので高価となる。このため、半導体受光素子、発光素子、導波路素子を一元的に半導体基板上に集積化することが望まれるが、そのためには簡易な半導体機能素子の作製プロセスの確立とともに、半導体光機能素子相互の結合効率を高める必要がある。

【０００３】さて、半導体基板上に半導体レーザを集積化した場合、半導体レーザを発振させるには共振器を構成する必要がある関係上、反射鏡であるへき開面または回折格子の導入が不可欠である。この場合、回折格子の導入は作製工程が複雑となるため、結晶端面を用いたファブリ・ペローレーザが作製プロセスおよび価格の観点から有利である。しかし、光機能素子の集積回路の作製において結晶端面を有する半導体レーザを形成することは、端面形成用の溝が生じることになり、半導体レーザと光導波路や受光素子との間を直接結合することができず、結合部で光強度の大きな損失を生じることになる。

【０００４】図６は、従来の構成よりなる半導体レーザ１と光導波路２との集積構造で、溝５を介しての結合を模式的に表した平面図（ａ）および断面図（ｂ）である。ここでは、半導体レーザ１の片側に光導波路２を示してあるが、両側に光導波路部を形成する場合や、他方に導波路型受光素子部を形成する場合もあるが、ここでは半導体レーザ１とその片側の光導波路２との例を示す。

【０００５】

【発明が解決しようとする課題】このような半導体レーザ１と光導波路２との結合においては、それぞれのコア３，４を構成する半導体材料の屈折率が３．０以上と空気のそれと比べて大きいため、半導体材料を伝搬するビーム径が小さいほど、反射端面形成用の溝から空気中に出射した光波は大きな回折効果をうけ、放射状に広がることになる。このため、端面形成用の溝部５では散乱光が増大し、半導体レーザ１から導波路２への結合効率は低下してしまう。具体的には、半導体材料としてＩｎＰ系の発光波長１．５μｍの半導体レーザの場合には、溝の間隔を５μｍにすると、結合効率は１０％以下になってしまう。

【０００６】本発明は、半導体基板上に光機能素子を集積化する場合において、端面形成用溝を有する半導体レーザと光導波路との結合効率を高めることを目的とするものである。

【０００７】

【課題を解決するための手段】上記目的を達成するために、半導体基板上に共振器端面の一端を構成する溝を有する半導体レーザと、前記の溝を介して前記半導体レーザと結合された光導波路とを有する光デバイスにおいて、請求項１記載の発明は、前記半導体レーザと光導波路のコア幅を前記溝近傍においてテーパ状に縮小した構

造を有するものであり、請求項２記載の発明は、前記半導体レーザおよび光導波路のコアが第一の内部のコアと第二の外部のコアからなる二重コア構造を有し、該第一のコア幅が溝近傍でテーパ状に縮小しているものであり、請求項３記載の発明は、前記半導体レーザおよび光導波路のコア幅が前記溝近傍でテーパ状に縮小するとともに、該溝の半導体レーザ側端面が光軸に対して垂直をなし、かつ該溝の導波路側端面が光軸に対して傾斜させた構造を有するものであり、さらに、半導体基板上に半導体レーザと、前記半導体レーザと結合された光導波路からなる光デバイスにおいて、請求項４記載の発明は、前記半導体レーザと光導波路のコア幅が結合部でテーパ状に縮小しつつ接続され、該結合部において該半導体レーザ側で光軸に対して垂直な端面をなし、かつ該光導波路側で該結合部に近づくに従いテーパ状コアに近接するような溝を有するものであり、請求項５記載の発明は、前記半導体レーザと光導波路のコア幅が結合部でテーパ状に縮小しつつ接続され、該結合部において該半導体レーザ側で光軸に対して垂直な端面をなし、かつ該導波路側で半導体基板の厚さ方向にＶ字形状となる溝を有するものをそれぞれ特徴とする。

【０００８】

【作用】上記の構成をとることにより、端面形成用の溝部においてテーパ状コアの存在により導波光のモードフィールド径を拡大して回折効果を低減することになり、半導体レーザと導波路との高い結合効率を実現するものである。

【０００９】

【実施例】以下、図１～図５を参照して実施例にもとずいて詳細に説明する。

（実施例１）図１は第一の発明の実施例を示した平面図（ａ）および断面図（ｂ）で、半導体レーザ１のコア３と導波路部２のコア４の両者が、溝５の方向に向かうに従い平面からみたコア幅を細めて（以後、テーパコア６と称する。）おり、溝５近傍ではそのコア幅はもとの五分の一程度に縮小した構造を有している。

【００１０】このため、半導体レーザ１からの導波光はこのテーパコア６のため伝搬損失を生じることなく、溝５端面でモードフィールド径が著しく拡大される。モードフィールド径が拡大されていることにより溝５に出射した導波光は溝５伝搬中の回折効果が小さく、溝５の導波路側の端面におけるモードフィールド径は溝５への出射前のモードフィールド径とほとんど変化しない。一方、導波路側のコア幅も半導体レーザ１側と同様溝５から離れるに従い徐々に広がっていることから、溝５端面で拡大されていたモードフィールド径は再び導波路コア４の大きさで決まる大きさに戻る。従って、溝５近傍では拡大されたビーム同士の結合となるため、従来のコア幅が同一寸法に比べて、結合効率が著しく向上することになる。なお、回折効果を小さくするだけの場合には、半導体レーザ１のコア３をテーパ状にすればよいが、結合効率は導波路２側との間でモード形状を整合させかつ開口角をゆるく採れることで著しく向上し、よって導波路２側でも溝５側にてテーパコア６を設けている。

【００１１】なお、本実施例ではレーザの共振器の構成を、一方の端面を溝５のレーザ側端面に、他方の端面を通常のへき開端面としているが、レーザの両側に溝５を構成しても良い。実際に、活性層の厚さが０．２５μｍでコア幅が１．５μｍのＩｎＰ系レーザにおいては、溝３でのコア幅を０．２５μｍとなるテーパコアを作製した結果、溝間隔が５μｍまでは結合損失の増加は観測できなかった。

【００１２】（実施例２）図２は第二の発明の実施例を示した平面図（ａ）および断面図（ｂ）で、本実施例では製作上の簡易さから半導体レーザ１、テーパ接続部、導波路２全体にわたって二重導波路構造を採用した例を示してある。すなわち、第１の内部コア３及びコア４とこの内部コア３，４を囲む第２の外部コア７からなり、第１の内部コア３，４はそれぞれ溝５近傍でテーパコア６となり、溝５端部では第一のコア３，４が消失している。

【００１３】この構造では、外部コア７とクラッド８との屈折率差がきわめて小さいので、導波光は半導体レーザ１と導波路２では外部コア７をクラッド８と感じて内部コア３および４に閉じ込められるが、接続部では内部コアが消失するために外部コア７に閉じ込められる。すなわち、テーパ６の先端でコアが消失している場合でも導波構造は保たれ、単一モード条件が溝５の両側で維持される。

【００１４】外部コア５の幅および厚さは１０～２０μｍとすることができるので、導波光のモードフィールド径を半導体レーザ１のモードフィールド径より１桁以上大きくすることができ、溝５での回折を小さくして結合効率を高めることができる。

【００１５】（実施例３）図３に第三の発明の実施例を示した平面図（ａ）および断面図（ｂ）である。本実施例では溝５の導波路２側端面をレーザ１のコア３の軸に対してやや傾斜させるとともに、導波路コア４の軸がレーザコア３の軸に対して傾斜させて形成したものである。本実施例でも溝５近傍ではコア３，４の幅はテーパコア６のように縮小している。本実施例では溝５の導波路側端面をわずかに傾けることにより、溝５の導波路２側端面で反射した光が半導体レーザコア３に再結合する割合を低減することができる。

【００１６】なお、図３に示すように、導波路コア４の光軸は溝５の導波路側端面の傾斜角θによる導波光の屈折角に合わせて設定しておくと、レーザコア３から導波路コア４への結合における傾斜角θによる過剰損失を無視でき、導波路部コアへの結合効率を高めることができる。もっとも、半導体レーザ１と導波路２との配置上の

理由から、導波路２の光軸を傾斜させることなく、導波路端面に傾斜を設けるだけでも反射光によるコア３への再結合を低減できる。なお、本実施例では平面からみて図３（ａ）の如く傾斜角θを与えたが、側面からみて図３（ｂ）上において傾斜角を与えてもよい。更に、本実施例は図２に示す二重コア構造に対しても応用可能である。本実施例の最大の特徴は、第一の実施例においては溝５に出射した光が導波路部との境界でも反射されるため、半導体レーザ部は溝５の両側端面を反射面とする複合共振器構造となり、半導体レーザ発振しきい値電流の変動などを招くが、本実施例によりこの特性の劣化を防止することにある。

【００１７】（実施例４）図４に第四の発明の実施例を示した平面図（ａ）および断面図（ｂ）を示す。半導体レーザ１と導波路２の結合部にむけて両者のコア幅３および４をテーパコア６Ｈおよび６Ｆに示すように細めていき、所定の最小のコア幅でコア同士を接続してある。さらに、結合部においては、半導体レーザ１側で光軸に対して垂直な端面で、導波路２側で図のように細いテーパコア６Ｆの横方向に切り込み（凹）型の溝５が近接するように形成してある。この溝５の作製は、反応性ガスを用いたイオンエッチングや化学溶液によるエッチングで形成できる。

【００１８】このような構造においては、半導体レーザ１からの導波光は伝搬損失が増大することなくそのモードフィールド径が拡大されてテーパコア６Ｈ領域を伝搬する。この時モードフィールド径が拡大されているのでテーパコア６Ｈ領域から浸みだした光強度分布については、切り込み溝５の端面は、反射面として働く。一方、導波路２のコア４の軸に対して垂直とならない溝５の導波路側境界面は、レンズ効果により溝５の空間に放出された光波を導波路２のコア４への結合させる。

【００１９】なお、図４では、拡大されたモードフィールド径のうち溝５をすり抜けて光導波路部２へ達する光の分布に整合させて結合効率を高めるために、導波路４のテーパコア６Ｆのコア幅と半導体レーザ１のテーパコア６Ｈのコア幅とは異なる例を示してある。

【００２０】本実施例では溝５はコア層にはなく、クラッド層に形成した。一般に、コア層は多重量子井戸層等を用いる場合が多く、クラッド層はＩｎＰあるいはＩｎＧａＡｓＰ等の均一組成の材料で構成される場合が多い。従って、本実施例の構造は加工しやすいクラッド層のみを加工すればよいという利点がある。また、溝５がテーパコア６Ｆに浸入し、半導体レーザ１と導波路２が空隙により分離されても本発明の基本的な動作は行われる。

【００２１】（実施例５）図５に第五の発明の実施例の平面図（ａ）および断面図（ｂ）を示す。本実施例では半導体レーザ１と導波路２の両コアはテーパコア６により互いにそのコア幅を細めていき、結合部で所定の最小

幅コア９で接続されている。さらに、結合部においては、半導体レーザ側で光軸に対して垂直な端面をなし、かつ導波路側で半導体基板に図のような切り込み型のＶ字型の溝５が厚さ方向に形成されている。このような構造においては、実施例４と同様に、半導体レーザの反射面を形成するとともに、半導体レーザと導波路との結合を高めることができる。

【００２２】以上述べた実施例においては、溝の半導体レーザ側の端面に金属または誘電体多層膜からなる高反射膜を設けることにより、レーザ共振器の反射率を高めることができ、半導体レーザのしきい値電流を減少させることができる。

【００２３】また、テーパ構造は半導体レーザ側と導波路側で非対称でも良い。さらに、実施例においては導波路幅のみにテーパ形状を有する構成例を示したが、モードフィールド径を拡大すれば導波路幅および厚さの両者にテーパ形状を持たせても良い。また、半導体レーザおよび導波路のテーパ状導波路幅の変化を直線的に変化させて示してあるが、放物線や指数関数等の関数形でもよい。

【００２４】

【発明の効果】以上述べたように、本発明によれば、半導体基板上への半導体光機能素子の集積化においては、半導体光機能素子相互の結合を高い光結合効率により実現することができる。とくに、実用の半導体作製技術により光機能素子の集積化が実現できるので、安価で信頼性の高い光部品を提供することができる。

【図面の簡単な説明】

【図１】第一の実施例を示す平面図および断面図である。

【図２】第二の実施例を示す平面図および断面図である。

【図３】第三の実施例を示す平面図および断面図である。

【図４】第四の実施例を示す平面図および断面図である。

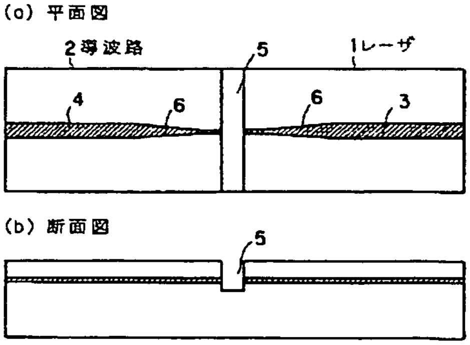
【図５】第五の実施例を示す平面図および断面図である。

【図６】従来の構成よりなる半導体レーザと導波路との結合を示した平面図および断面図である。

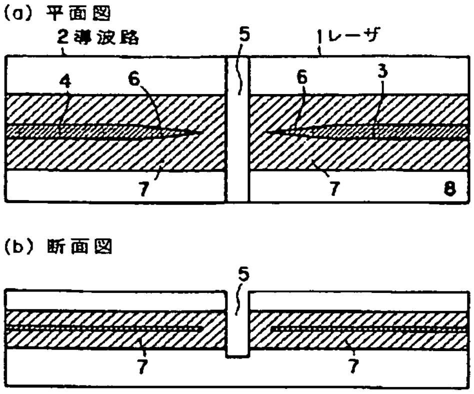
【符号の説明】

１	半導体レーザ
２	導波路
３	レーザのコア
４	導波路のコア
５	溝
６，６Ｈ，６Ｆ	テーパコア
７	外部コア
８	クラッド
９	最小幅コア

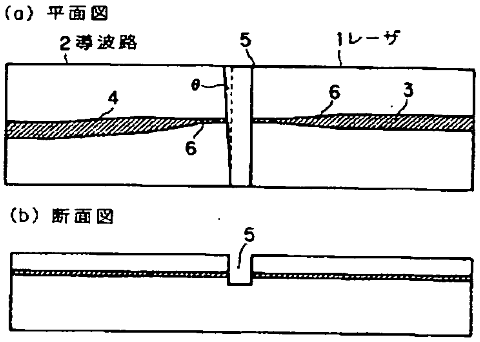
【図１】



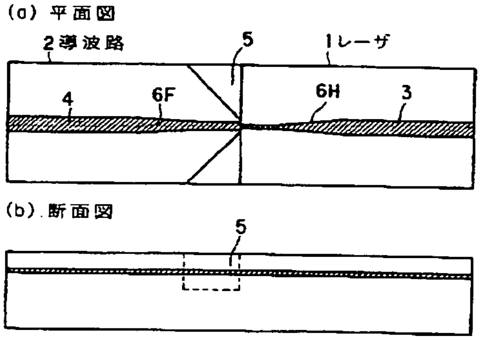
【図２】



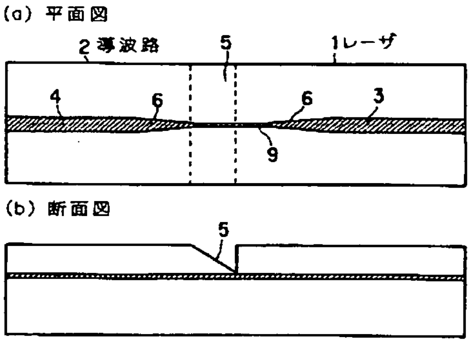
【図３】



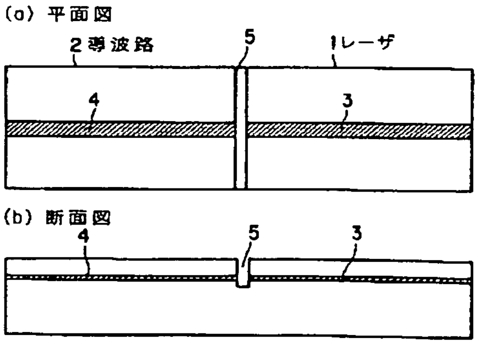
【図４】



【図５】



【図６】



フロントページの続き

(72)発明者　鈴木　安弘
東京都千代田区内幸町一丁目１番６号　日
本電信電話株式会社内

(72)発明者　三冨　修
東京都千代田区内幸町一丁目１番６号　日
本電信電話株式会社内

(72)発明者　永沼　充
東京都千代田区内幸町一丁目１番６号　日
本電信電話株式会社内

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CLAIMS

[Claim(s)]

[Claim 1] The optical device characterized by having the structure which each core width of face of said semiconductor laser and waveguide reduced in the shape of a taper [near / said / the slot] in the optical device which has the semiconductor laser which has the slot which constitutes the end of a resonator end face on a semi-conductor substrate, and the waveguide combined with said semiconductor laser through the aforementioned slot.

[Claim 2] In the optical device which has the semiconductor laser which has the slot which constitutes the end of a resonator end face on a semi-conductor substrate, and the waveguide combined with said semiconductor laser through the aforementioned slot The optical device characterized by having the duplex core fabric which each core with said semiconductor laser and waveguide becomes from the core of the second exterior surrounding the core of the first interior, and the core of this interior, and reducing in the shape of a taper near the core width-of-face fang furrow of this first.

[Claim 3] In the optical device which has the semiconductor laser which has the slot which constitutes the end of a resonator end face on a semi-conductor substrate, and the waveguide combined with said semiconductor laser through the aforementioned slot The optical device with which the semiconductor laser side edge side of this slot is characterized by having the structure where the waveguide side edge side of nothing and this slot made the perpendicular incline to an optical axis to an optical axis while said semiconductor laser and each core width of face of waveguide contract in the shape of a taper near [said] the slot.

[Claim 4] The optical device characterized by having a slot which approaches a taper-like core as it connects in the optical device which consists of waveguide combined with semiconductor laser and said semiconductor laser on the semi-conductor substrate, each core width of face of said semiconductor laser and waveguide contracting in the shape of a taper by the bond part and this bond part is approached by this nothing and waveguide side in a perpendicular end face to an optical axis in this bond part by this semiconductor laser side.

[Claim 5] The optical device characterized by having the slot which is connected in the optical device which consists of waveguide combined with semiconductor laser and said semiconductor laser on the semi-conductor substrate , each core width of face of said semiconductor laser and waveguide contracting in the shape of a taper by the bond part , and serves as a V character configuration in the thickness direction of a semi-conductor substrate by this nothing and waveguide side in a perpendicular end face to an optical axis in this bond part by this semiconductor laser side .

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the semi-conductor integration light source used for optical communication, or optical measurement, optical exchange, etc.
[0002]
[Description of the Prior Art] Although semiconductor laser is used as the light source of optical communication and the optical measurement field, in order to aim at improvement in a function, integration of the light source, waveguide, and an electric eye is required. As a conventional integration module, the PLC circuit and semi-conductor light emitting device which consisted of quartz system waveguides, and a semi-conductor photo detector are accumulated on a hybrid, for example, and there are pig tail die parts which combined the optical fiber. However, since the alignment of micron order is the need, the modularization technique of this semi-conductor light emitting device and a photo detector becomes expensive. For this reason, although to integrate a semi-conductor photo detector, a light emitting device, and a waveguide component on a semi-conductor substrate unitary is desired, it is necessary to raise the joint effectiveness between semi-conductor optoelectronic devices with establishment of the production process of a semi-conductor functional device simple for that purpose.
[0003] Now, when semiconductor laser is integrated on a semi-conductor substrate, installation of the cleavage plane or diffraction grating which is a reflecting mirror is indispensable on the relation which needs to constitute a resonator to oscillate semiconductor laser. In this case, since a making process becomes complicated, installation of a diffraction grating has the advantageous Fabry-Perot laser using a crystal end face from a viewpoint of a production process and a price. However, the slot for end-face formation will be generated, forming the semiconductor laser which has a crystal end face in production of the integrated circuit of an optoelectronic device cannot couple directly between semiconductor laser, and optical waveguides or photo detectors, but it will produce big loss of optical reinforcement in a bond part.
[0004] Drawing 6 is the accumulation structure of the semiconductor laser 1 and optical waveguide 2 which consist of the conventional configuration, and is the top view (a) and sectional view (b) which expressed association through a slot 5 typically. Although the waveguide mold photo detector section may be formed in the case where the optical waveguide section is formed in both sides although optical waveguide 2 is shown in one side of semiconductor laser 1, and another side, the example of semiconductor laser 1 and the optical waveguide 2 of the one side is shown here.
[0005]
[Problem(s) to be Solved by the Invention] In association with such semiconductor laser 1 and optical waveguide 2, the light wave which carried out outgoing radiation into air from the slot for reflective end-face formation will receive the big diffraction effect, and will spread in a radial, so that the beam diameter to which the refractive index of the semiconductor material which constitutes each core 3 and 4 spreads a semiconductor material since it is large compared with 3.0 or more and it of air is small. For this reason, in the slot 5 for end-face formation, the scattered light will increase and the joint

effectiveness from semiconductor laser 1 to waveguide 2 will fall. If spacing of a slot is set to 5 micrometers as a semiconductor material in the case of semiconductor laser with a luminescence wavelength [of an InP system] of 1.5 micrometers, specifically, joint effectiveness will become 10% or less.

[0006] This invention aims at raising the joint effectiveness of the semiconductor laser and optical waveguide which have a slot for end-face formation, when integrating an optoelectronic device on a semi-conductor substrate.

[0007]

[Means for Solving the Problem] In the optical device which has the semiconductor laser which has the slot which constitutes the end of a resonator end face on a semi-conductor substrate, and the optical waveguide combined with said semiconductor laser through the aforementioned slot in order to attain the above-mentioned purpose Invention according to claim 1 is what has the structure which reduced the core width of face of said semiconductor laser and optical waveguide in the shape of a taper [near / said / the slot]. Invention according to claim 2 It has the duplex core fabric which the core of said semiconductor laser and optical waveguide becomes from the core of the first interior, and the core of the second exterior. It is what is being reduced in the shape of a taper near the core width-of-face fang furrow of this first. Invention according to claim 3 While said semiconductor laser and the core width of face of optical waveguide contract in the shape of a taper near [said] the slot The semiconductor laser side edge side of this slot is what has the structure where the waveguide side edge side of nothing and this slot made the perpendicular incline to an optical axis to an optical axis. On a semi-conductor substrate further Semiconductor laser, In the optical device which consists of optical waveguide combined with said semiconductor laser invention according to claim 4 It connects the core width of face of said semiconductor laser and optical waveguide contracting in the shape of a taper by the bond part. In this bond part, an optical axis is received by this semiconductor laser side. A perpendicular end face Nothing, It is what has a slot which approaches a taper-like core as this bond part is approached by this optical waveguide side. And invention according to claim 5 It connects the core width of face of said semiconductor laser and optical waveguide contracting in the shape of a taper by the bond part, and is characterized by what has the slot which serves as a V character configuration in the thickness direction of a semi-conductor substrate by this nothing and waveguide side in a perpendicular end face to an optical axis in this bond part by this semiconductor laser side, respectively.

[0008]

[Function] By taking the above-mentioned configuration, in the slot for end-face formation, the diameter of the mode field of guided wave light will be expanded by existence of a taper-like core, the diffraction effect will be reduced, and high joint effectiveness of semiconductor laser and waveguide is realized.

[0009]

[Example] the following, drawing 1 - drawing 5 -- referring to -- an example -- a basis -- it explains to a ****** detail.

(Example 1) The core width of face seen from the flat surface is narrowed, and it gets down (the taper core 6 is called henceforth.), and has the structure which reduced the core width of face to about [of the half a sum of a basis] one in about five slot as drawing 1 is the top view (a) and sectional view (b) having shown the example of the first invention and both core 3 of semiconductor laser 1 and core 4 of the waveguide section 2 go in the direction of a slot 5.

[0010] For this reason, the diameter of the mode field is remarkably expanded by slot 5 end face, without the guided wave light from semiconductor laser 1 producing a propagation loss for this taper core 6. By expanding the diameter of the mode field, the guided wave light which carried out outgoing radiation to the slot 5 has the small diffraction effect under slot 5 propagation, and the diameter of the mode field in the end face by the side of the waveguide of a slot 5 hardly changes with the diameter of the mode field in front of the outgoing radiation to a slot 5. Since it is spreading gradually on the other hand as it separates from a slot 5 like [the core width of face by the side of waveguide] a semiconductor laser 1 side, the diameter of the mode field expanded by slot 5 end face returns to the magnitude again decided by magnitude of the waveguide core 4. Therefore, in about five slot, since it becomes association of the expanded beams, compared with the same dimension, joint effectiveness of conventional core width of face will improve remarkably. In addition, although what is necessary is just to make the core 3 of semiconductor laser 1 into the shape of a taper, joint effectiveness improved to the case which makes the diffraction effect small remarkably by a mode configuration being adjusted between waveguide 2 sides, and angular aperture being taken loosely, and, therefore, the waveguide 2 side has also formed the taper core 6 in it in the slot 5 side.

[0011] In addition, although the other-end side is made [the configuration of the resonator of laser] into the usual cleavage end face for one end face in the laser side edge side of a slot 5, a slot 5 may consist of this examples on both sides of laser. As a result of producing the taper core from which the thickness of a barrier layer is actually set to 0.25 micrometers in the core width of face in a slot 3 in the InP system laser whose core width of face is 1.5 micrometers by 0.25 micrometers, the increment in slot spacing's joint loss of 5 micrometers was not able to be observed.

[0012] (Example 2) Drawing 2 is the top view (a) and sectional view (b) having shown the example of the second invention, and has shown the example which adopted duplex waveguide structure over semiconductor laser 1, a taper connection, and the waveguide 2 whole from simple [on manufacture] by this example. That is, it consisted of the 2nd external core 7 surrounding the 1st internal core 3 and core 4, and these internal cores 3 and 4, and the 1st internal core 3 and 4 turned into the taper core 6 in about five slot, respectively, and the first core 3 and 4 has disappeared at the slot 5 edge.

[0013] With this structure, since the refractive-index difference of the external core 7 and a clad 8 is very small, in semiconductor laser 1 and waveguide 2, guided wave light senses the external core 7 as a clad 8, and is shut up by the internal cores 3 and 4, but in a connection, in order that an internal core may disappear, it is shut up by the external core 7. That is, even when the core has disappeared at the tip of a taper 6, guided wave structure is maintained and is maintained on both sides of the single mode condition fang furrow 5.

[0014] Since the width of face and thickness of the external core 5 can be set to 10-20 micrometers, the diameter of the mode field of guided wave light can be made larger single or more figures than the diameter of the mode field of semiconductor laser 1, diffraction in a slot 5 can be made small, and joint effectiveness can be raised.

[0015] (Example 3) It is the top view (a) and sectional view (b) having shown the example of the third invention in drawing 3 . In this example, while making the waveguide 2 side-edge side of a slot 5 incline a little to the shaft of the core 3 of laser 1, the shaft of the waveguide core 4 makes it incline to the shaft of the laser core 3, and forms. The width of face of cores 3 and 4 is also reducing this example like the taper core 6 in about five slot. In this example, the rate which the light reflected in respect of the waveguide 2 side edge of a slot 5 recombines with the semiconductor laser core 3 can be reduced by leaning the waveguide side edge side of a slot 5 slightly.

[0016] In addition, as shown in drawing 3 , if the optical axis of the waveguide core 4 is set up according to the guided wave optical refraction angle by the tilt angle theta of the waveguide side edge side of a slot 5, it can disregard the superfluous loss by the tilt angle theta in association to the waveguide core 4 from the laser core 3, and can raise the joint effectiveness to a waveguide section core. But establishing an inclination in a waveguide end face can also reduce the recombination to the core 3 by the reflected light, without making the optical axis of waveguide 2 incline from the reasons of arrangement with semiconductor laser 1 and waveguide 2. In addition, although the tilt angle theta was given like drawing 3 (a) seen from the flat surface in this example, a tilt angle may be given on drawing 3 (b) seen from a side face. Furthermore, this example is applicable also to the duplex core fabric shown in drawing 2 . Although the semiconductor laser section serves as complex resonator structure which makes a reflector the both-sides end face of a slot 5 and fluctuation of a semiconductor laser oscillation threshold current etc. is cause since , as for the greatest description of this example , the light which carried out outgoing radiation to the slot 5 is reflect in the first example also on a boundary with the waveguide section , it is in prevent degradation of this property by this example .

[0017] (Example 4) The top view (a) and sectional view (b) having shown the example of the fourth invention in drawing 4 are shown. Both core width of face 3 and 4 is narrowed as shown in the taper cores 6H and 6F towards the bond part of semiconductor laser 1 and waveguide 2, and cores are connected by the minimum predetermined core width of face. Furthermore, in the bond part, it is a perpendicular end face to an optical axis in a semiconductor laser 1 side, and it has formed so that it may cut deeply in the thin longitudinal direction of taper core 6F by the waveguide 2 side as shown in drawing (concave), and the slot 5 on the mold may approach. Production of this slot 5 can be formed by etching by the ion etching and the chemical solution which used reactant gas.

[0018] In such structure, without a propagation loss increasing, the diameter of the mode field is expanded and the guided wave light from semiconductor laser 1 spreads taper core 6H field. About the optical intensity distribution which began to permeate from taper core 6H field since the diameter of the mode field was expanded at this time, the end face of the slitting slot 5 works as a reflector. the light wave by which the waveguide side interface of the slot 5 which does not become perpendicular to the shaft of the core 4 of waveguide 2 was emitted to the space of a slot 5 by the lens effectiveness on the other hand -- the core 4 of waveguide 2 -- it is made to join together

[0019] In addition, by drawing 4 , in order to adjust distribution of the light which passes through a slot 5 among the expanded diameters of the mode field, and is attained to the optical waveguide section 2 and to raise joint effectiveness, the core width of face of taper core 6F of waveguide 4 and the core width of face of taper core 6H of semiconductor laser 1 have shown a different example.

[0020] In this example, there is no slot 5 in a core layer, and it was formed in the cladding layer. Generally, a cladding layer consists of ingredients of homogeneity presentations, such as InP or InGaAsP, for a core layer in many cases, using a multiplex quantum well layer etc. in many cases. Therefore, the structure of this example has the advantage that what is necessary is to process only the cladding layer which is easy to process it. Moreover, a slot 5 infiltrates into taper core 6F, and even if semiconductor laser 1 and waveguide 2 are separated by the opening, fundamental actuation of this invention is performed.

[0021] (Example 5) The top view (a) and sectional view (b) of an example of the fifth invention are shown in drawing 5 . In this example, both the cores of semiconductor laser 1 and waveguide 2 narrow the core width of face mutually with the taper core 6, and are connected with the minimum width-of-face core 9 predetermined by the bond part. Furthermore, in the bond part, the slot 5 of the V character mold of a slitting mold as shown in drawing is formed in the thickness direction by the nothing and waveguide side in the perpendicular end face to the optical axis at the semi-conductor substrate by the semiconductor laser side. In such structure, like an example 4, while forming the reflector of semiconductor laser, association with semiconductor laser and waveguide can be raised.

[0022] In the example described above, by preparing the high reflective film which becomes an end face by the side of the semiconductor laser of a slot from a metal or dielectric multilayers, the reflection factor of a laser cavity can be raised and the threshold current of semiconductor laser can be decreased.

[0023] Moreover, asymmetry is sufficient as taper structure at a semiconductor laser and waveguide side. Furthermore, although the example of a configuration which has a taper configuration only to waveguide width of face in an example was shown, a taper configuration may be given to both waveguide width of face and thickness as long as it expands the diameter of the mode field. Moreover, although change of semiconductor laser and the taper-like waveguide width of face of waveguide is changed linearly and it is shown, function forms, such as a parabola and an exponential function, are sufficient.

[0024]

[Effect of the Invention] As stated above, according to this invention, in integration of the semi-conductor optoelectronic device to a semi-conductor substrate top, association between semi-conductor optoelectronic devices is realizable with high optical coupling effectiveness. Since integration of an optoelectronic device is realizable especially with the semi-conductor production technique of practical use, it is cheap and reliable optical components can be offered.

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TECHNICAL FIELD

[Industrial Application] This invention relates to the semi-conductor integration light source used for optical communication, or optical measurement, optical exchange, etc.

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PRIOR ART

[Description of the Prior Art] Although semiconductor laser is used as the light source of optical communication and the optical measurement field, in order to aim at improvement in a function, integration of the light source, waveguide, and an electric eye is required. As a conventional integration module, the PLC circuit and semi-conductor light emitting device which consisted of quartz system waveguides, and a semi-conductor photo detector are accumulated on a hybrid, for example, and there are pig tail die parts which combined the optical fiber. However, since the alignment of micron order is the need, the modularization technique of this semi-conductor light emitting device and a photo detector becomes expensive. For this reason, although to integrate a semi-conductor photo detector, a light emitting device, and a waveguide component on a semi-conductor substrate unitary is desired, it is necessary to raise the joint effectiveness between semi-conductor optoelectronic devices with establishment of the production process of a semi-conductor functional device simple for that purpose.
[0003] Now, when semiconductor laser is integrated on a semi-conductor substrate, installation of the cleavage plane or diffraction grating which is a reflecting mirror is indispensable on the relation which needs to constitute a resonator to oscillate semiconductor laser. In this case, since a making process becomes complicated, installation of a diffraction grating has the advantageous Fabry-Perot laser using a crystal end face from a viewpoint of a production process and a price. However, the slot for end-face formation will be generated, forming the semiconductor laser which has a crystal end face in production of the integrated circuit of an optoelectronic device cannot couple directly between semiconductor laser, and optical waveguides or photo detectors, but it will produce big loss of optical reinforcement in a bond part.
[0004] Drawing 6 is the accumulation structure of the semiconductor laser 1 and optical waveguide 2 which consist of the conventional configuration, and is the top view (a) and sectional view (b) which expressed association through a slot 5 typically. Although the waveguide mold photo detector section may be formed in the case where the optical waveguide section is formed in both sides although optical waveguide 2 is shown in one side of semiconductor laser 1, and another side, the example of semiconductor laser 1 and the optical waveguide 2 of the one side is shown here.

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EFFECT OF THE INVENTION

[Effect of the Invention] As stated above, according to this invention, in integration of the semi-conductor optoelectronic device to a semi-conductor substrate top, association between semi-conductor optoelectronic devices is realizable with high optical coupling effectiveness. Since integration of an optoelectronic device is realizable especially with the semi-conductor production technique of practical use, it is cheap and reliable optical components can be offered.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] In association with such semiconductor laser 1 and optical waveguide 2, the light wave which carried out outgoing radiation into air from the slot for reflective end-face formation will receive the big diffraction effect, and will spread in a radial, so that the beam diameter to which the refractive index of the semiconductor material which constitutes each core 3 and 4 spreads a semiconductor material since it is large compared with 3.0 or more and it of air is small. For this reason, in the slot 5 for end-face formation, the scattered light will increase and the joint effectiveness from semiconductor laser 1 to waveguide 2 will fall. If spacing of a slot is set to 5 micrometers as a semiconductor material in the case of semiconductor laser with a luminescence wavelength [of an InP system] of 1.5 micrometers, specifically, joint effectiveness will become 10% or less.
[0006] This invention aims at raising the joint effectiveness of the semiconductor laser and optical waveguide which have a slot for end-face formation, when integrating an optoelectronic device on a semi-conductor substrate.

[Translation done.]

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MEANS

[Means for Solving the Problem] In the optical device which has the semiconductor laser which has the slot which constitutes the end of a resonator end face on a semi-conductor substrate, and the optical waveguide combined with said semiconductor laser through the aforementioned slot in order to attain the above-mentioned purpose Invention according to claim 1 is what has the structure which reduced the core width of face of said semiconductor laser and optical waveguide in the shape of a taper [near / said / the slot]. Invention according to claim 2 It has the duplex core fabric which the core of said semiconductor laser and optical waveguide becomes from the core of the first interior, and the core of the second exterior. It is what is being reduced in the shape of a taper near the core width-of-face fang furrow of this first. Invention according to claim 3 While said semiconductor laser and the core width of face of optical waveguide contract in the shape of a taper near [said] the slot The semiconductor laser side edge side of this slot is what has the structure where the waveguide side edge side of nothing and this slot made the perpendicular incline to an optical axis to an optical axis. On a semi-conductor substrate further Semiconductor laser, In the optical device which consists of optical waveguide combined with said semiconductor laser invention according to claim 4 It connects the core width of face of said semiconductor laser and optical waveguide contracting in the shape of a taper by the bond part. In this bond part, an optical axis is received by this semiconductor laser side. A perpendicular end face Nothing, It is what has a slot which approaches a taper-like core as this bond part is approached by this optical waveguide side. And invention according to claim 5 It connects the core width of face of said semiconductor laser and optical waveguide contracting in the shape of a taper by the bond part, and is characterized by what has the slot which serves as a V character configuration in the thickness direction of a semi-conductor substrate by this nothing and waveguide side in a perpendicular end face to an optical axis in this bond part by this semiconductor laser side, respectively.

[Translation done.]

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OPERATION

[Function] By taking the above-mentioned configuration, in the slot for end-face formation, the diameter of the mode field of guided wave light will be expanded by existence of a taper-like core, the diffraction effect will be reduced, and high joint effectiveness of semiconductor laser and waveguide is realized.

[Translation done.]

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EXAMPLE

[Example] the following, drawing 1 - drawing 5 -- referring to -- an example -- a basis -- it explains to a ****** detail.
(Example 1) Drawing 1 is the top view (a) and sectional view (b) having shown the example of the first invention, the core width of face seen from the flat surface is narrowed, and the core width of face has the structure reduced to about [of the half a sum of a basis] one in the cage (the taper core 6 is called henceforth.) and about five slot as both core 3 of semiconductor laser 1 and core 4 of the waveguide section 2 go in the direction of a slot 5.
[0010] For this reason, the diameter of the mode field is remarkably expanded by slot 5 end face, without the guided wave light from semiconductor laser 1 producing a propagation loss for this taper core 6. By expanding the diameter of the mode field, the guided wave light which carried out outgoing radiation to the slot 5 has the small diffraction effect under slot 5 propagation, and the diameter of the mode field in the end face by the side of the waveguide of a slot 5 hardly changes with the diameter of the mode field in front of the outgoing radiation to a slot 5. Since it is spreading gradually on the other hand as it separates from a slot 5 like [the core width of face by the side of waveguide] a semiconductor laser 1 side, the diameter of the mode field expanded by slot 5 end face returns to the magnitude again decided by magnitude of the waveguide core 4. Therefore, in about five slot, since it becomes association of the expanded beams, compared with the same dimension, joint effectiveness of conventional core width of face will improve remarkably. In addition, although what is necessary is just to make the core 3 of semiconductor laser 1 into the shape of a taper, joint effectiveness improved to the case which makes the diffraction effect small remarkably by a mode configuration being adjusted between waveguide 2 sides, and angular aperture being taken loosely, and, therefore, the waveguide 2 side has also formed the taper core 6 in it in the slot 5 side.
[0011] In addition, although the other-end side is made [the configuration of the resonator of laser] into the usual cleavage end face for one end face in the laser side edge side of a slot 5, a slot 5 may consist of this examples on both sides of laser. As a result of producing the taper core from which the thickness of a barrier layer is actually set to 0.25 micrometers in the core width of face in a slot 3 in the InP system laser whose core width of face is 1.5 micrometers by 0.25 micrometers, the increment in slot spacing's joint loss of 5 micrometers was not able to be observed.
[0012] (Example 2) Drawing 2 is the top view (a) and sectional view (b) having shown the example of the second invention, and has shown the example which adopted duplex waveguide structure over semiconductor laser 1, a taper connection, and the waveguide 2 whole from simple [on manufacture] by this example. That is, it consisted of the 2nd external core 7 surrounding the 1st internal core 3 and core 4, and these internal cores 3 and 4, and the 1st internal core 3 and 4 turned into the taper core 6 in about five slot, respectively, and the first core 3 and 4 has disappeared at the slot 5 edge.
[0013] With this structure, since the refractive-index difference of the external core 7 and a clad 8 is very small, in semiconductor laser 1 and waveguide 2, guided wave light senses the external core 7 as a clad 8, and is shut up by the internal cores 3 and 4, but in a connection, in order that an internal core may disappear, it is shut up by the external core 7. That is, even when the core has disappeared at the tip

of a taper 6, guided wave structure is maintained and is maintained on both sides of the single mode condition fang furrow 5.

[0014] Since the width of face and thickness of the external core 5 can be set to 10-20 micrometers, the diameter of the mode field of guided wave light can be made larger single or more figures than the diameter of the mode field of semiconductor laser 1, diffraction in a slot 5 can be made small, and joint effectiveness can be raised.

[0015] (Example 3) It is the top view (a) and sectional view (b) having shown the example of the third invention in drawing 3 . In this example, while making the waveguide 2 side-edge side of a slot 5 incline a little to the shaft of the core 3 of laser 1, the shaft of the waveguide core 4 makes it incline to the shaft of the laser core 3, and forms. The width of face of cores 3 and 4 is also reducing this example like the taper core 6 in about five slot. In this example, the rate which the light reflected in respect of the waveguide 2 side edge of a slot 5 recombines with the semiconductor laser core 3 can be reduced by leaning the waveguide side edge side of a slot 5 slightly.

[0016] In addition, as shown in drawing 3 , if the optical axis of the waveguide core 4 is set up according to the guided wave optical refraction angle by the tilt angle theta of the waveguide side edge side of a slot 5, it can disregard the superfluous loss by the tilt angle theta in association to the waveguide core 4 from the laser core 3, and can raise the joint effectiveness to a waveguide section core. But establishing an inclination in a waveguide end face can also reduce the recombination to the core 3 by the reflected light, without making the optical axis of waveguide 2 incline from the reasons of arrangement with semiconductor laser 1 and waveguide 2. In addition, although the tilt angle theta was given like drawing 3 (a) seen from the flat surface in this example, a tilt angle may be given on drawing 3 (b) seen from a side face. Furthermore, this example is applicable also to the duplex core fabric shown in drawing 2 . Although the semiconductor laser section serves as complex resonator structure which makes a reflector the both-sides end face of a slot 5 and fluctuation of a semiconductor laser oscillation threshold current etc. is cause since , as for the greatest description of this example , the light which carried out outgoing radiation to the slot 5 is reflect in the first example also on a boundary with the waveguide section , it is in prevent degradation of this property by this example .

[0017] (Example 4) The top view (a) and sectional view (b) having shown the example of the fourth invention in drawing 4 are shown. Both core width of face 3 and 4 is narrowed as shown in the taper cores 6H and 6F towards the bond part of semiconductor laser 1 and waveguide 2, and cores are connected by the minimum predetermined core width of face. Furthermore, in the bond part, it is a perpendicular end face to an optical axis in a semiconductor laser 1 side, and it has formed so that it may cut deeply in the thin longitudinal direction of taper core 6F by the waveguide 2 side as shown in drawing (concave), and the slot 5 on the mold may approach. Production of this slot 5 can be formed by etching by the ion etching and the chemical solution which used reactant gas.

[0018] In such structure, without a propagation loss increasing, the diameter of the mode field is expanded and the guided wave light from semiconductor laser 1 spreads taper core 6H field. About the optical intensity distribution which began to permeate from taper core 6H field since the diameter of the mode field was expanded at this time, the end face of the slitting slot 5 works as a reflector. the light wave by which the waveguide side interface of the slot 5 which does not become perpendicular to the shaft of the core 4 of waveguide 2 was emitted to the space of a slot 5 by the lens effectiveness on the other hand -- the core 4 of waveguide 2 -- it is made to join together

[0019] In addition, by drawing 4 , in order to adjust distribution of the light which passes through a slot 5 among the expanded diameters of the mode field, and is attained to the optical waveguide section 2 and to raise joint effectiveness, the core width of face of taper core 6F of waveguide 4 and the core width of face of taper core 6H of semiconductor laser 1 have shown a different example.

[0020] In this example, there is no slot 5 in a core layer, and it was formed in the cladding layer. Generally, a cladding layer consists of ingredients of homogeneity presentations, such as InP or InGaAsP, for a core layer in many cases, using a multiplex quantum well layer etc. in many cases. Therefore, the structure of this example has the advantage that what is necessary is to process only the cladding layer which is easy to process it. Moreover, a slot 5 infiltrates into taper core 6F, and even if semiconductor laser 1 and waveguide 2 are separated by the opening, fundamental actuation of this invention is performed.

[0021] (Example 5) The top view (a) and sectional view (b) of an example of the fifth invention are shown in drawing 5 . In this example, both the cores of semiconductor laser 1 and waveguide 2 narrow the core width of face mutually with the taper core 6, and are connected with the minimum width-of-face core 9 predetermined by the bond part. Furthermore, in the bond part, the slot 5 of the V character mold of a slitting mold as shown in drawing is formed in the thickness direction by the nothing and waveguide side in the perpendicular end face to the optical axis at the semi-conductor substrate by the semiconductor laser side. In such structure, like an example 4, while forming the reflector of semiconductor laser, association with semiconductor laser and waveguide can be raised.

[0022] In the example described above, by preparing the high reflective film which becomes an end face by the side of the semiconductor laser of a slot from a metal or dielectric multilayers, the reflection factor of a laser cavity can be raised and the threshold current of semiconductor laser can be decreased.

[0023] Moreover, asymmetry is sufficient as taper structure at a semiconductor laser and waveguide side. Furthermore, although the example of a configuration which has a taper configuration only to waveguide width of face in an example was shown, a taper configuration may be given to both waveguide width of face and thickness as long as it expands the diameter of the mode field. Moreover, although change of semiconductor laser and the taper-like waveguide width of face of waveguide is changed linearly and it is shown, function forms, such as a parabola and an exponential function, are sufficient.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the top view and sectional view showing the first example.
[Drawing 2] It is the top view and sectional view showing the second example.
[Drawing 3] It is the top view and sectional view showing the third example.
[Drawing 4] It is the top view and sectional view showing the fourth example.
[Drawing 5] It is the top view and sectional view showing the fifth example.
[Drawing 6] It is the top view and sectional view having shown association with the semiconductor laser and waveguide which consist of the conventional configuration.
[Description of Notations]
1 Semiconductor Laser
2 Waveguide
3 Core of Laser
4 Core of Waveguide
5 Slot
6, 6H, 6F Taper core
7 External Core
8 Clad
9 The Minimum Width-of-Face Core

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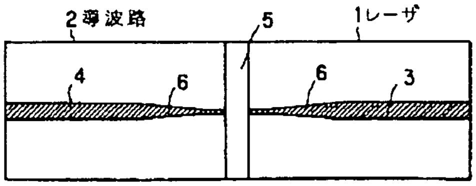
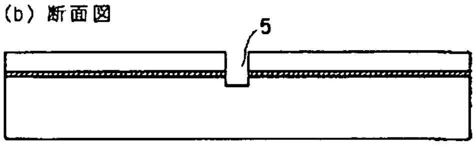
DRAWINGS

[Drawing 1]

(a) 平面図

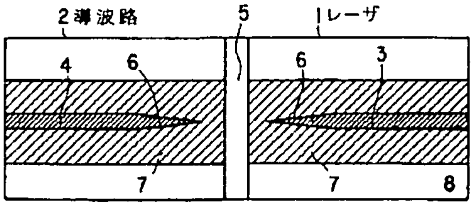


(b) 断面図



[Drawing 2]

(a) 平面図



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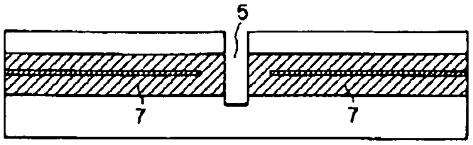
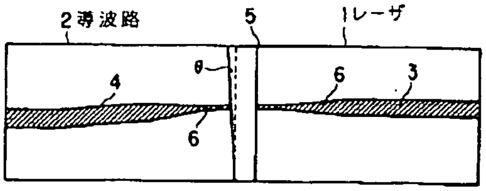
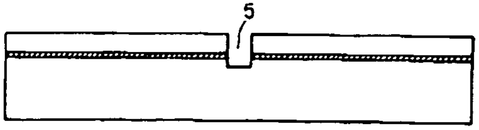


[Drawing 3]

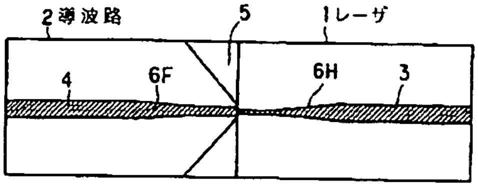
(a) 平面図



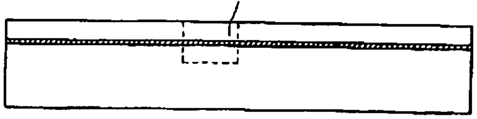
(b) 断面図



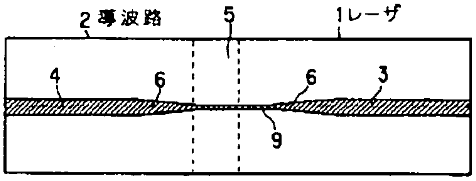
[Drawing 4]
(a) 平面図



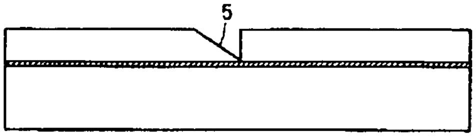
(b) 断面図



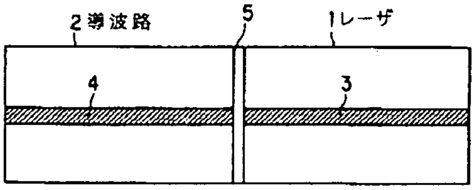
[Drawing 5]
(a) 平面図



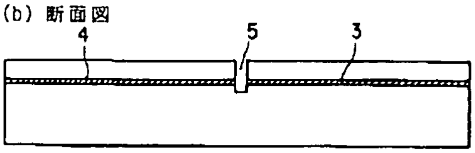
(b) 断面図



[Drawing 6]
(a) 平面図



(b) 断面図



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